Interactive Measures and Innovation

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ABSTRACT

The more an autonomous system is optimized to perform a task, the less intelligence it has to deal with unexpected changes in an uncertain environment. This paradox implies that in such environments, viability rather than optimization may be a more appropriate measure of a system's potential to carry out tasks. In this presentation I proposed that the function of innovation is to keep a system viable in response to change. To function autonomously in a dynamic environment, a constructed system has to be capable of innovating to some degree. This capacity can be modeled as a flexible repair and compensation mechanism. It can be measured with respect to specific tasks assigned to the system by having it react to selected imperfections and gauging the results. This presentation proposes that the capacity of a system to repair itself is a measure of its ability to act appropriately in uncertain environments. To examine this capacity, I explore a system architecture that could be tuned to enhance repair solutions.

KEYWORDS: Interaction, innovation, play, imperfection, remodeling, evolution, repair mechanisms.

1. INTRODUCTION

This paper attempts to gauge features that enable a constructed system to innovate. This task can only be pursued imperfectly since we don't have a firm grip even on the mechanisms of human innovation. Nobel laureate in Medicine Rita Levi-Montalcini noted in her book *In Praise of Imperfection*: "imperfection, rather than perfection, in the execution of our assigned or elected tasks is more in keeping with human nature." She believed in two factors more important than perfection. One is perseverance. The other is to underestimate difficulties that would make a more critical and acute person decide to avoid the task [1].

Although I acknowledge that this inquiry into innovation in constructed systems does underestimate the difficulties of the task, to invoke Montalcini-Levi in this introduction is not a way to justify the imperfections that are about to follow. What I do wish is to note from the start a possible link between imperfection and innovation, at least at the human level.

Secondly, Levi-Montalcini's comments allow us to reflect from the start on a matter of method. Attempting to model innovation in a constructed system is a way to explore in a practical cross-disciplinary way, unknowns about human innovation and how it might be enhanced. In other words, the attempt to produce elementary behaviors in constructed systems is an interactive way to model and illuminate how human innovation works.

2. A PRACTICAL VIEW OF INNOVATION

Innovation can be seen as carrying out a task or performing a function in a new way. One possible measure of innovation may well be the extent to which a system's performance is improved with respect to a task. This can be an internal measure, when the innovation is gauged in relation to what is already in the system, or an external measure when innovation is judged based on an environment outside the system. In this paper I will tend to focus on the simpler of the two measures: internal innovation. The results can be applied to external innovation, although gauging it may quickly become intractable in a natural environment.

In the arts, innovation could be finding new expressive means. For example, impressionism emerged as a new style that uses the effects of micro differences in textures. The designers of gothic cathedrals found structural ways to reach for the perceived divine. In literature, innovation could well be the development of magic realism or simply a new clever narrative. In the sciences, clear examples of innovation are the development of the periodic table of elements or the elaboration of mechanisms of evolution.

At a more clearly internal level, innovation is the impulse to reinvent foundations or remodel as a gateway to exploration. As Jean Piaget put it: "to understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition" [2]. Piaget suggests that the way to innovation through education is to cultivate experimental minds, to favor interdisciplinarity,

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and to mentor students so that even rote teaching makes them feel they are inventing what they are learning. Howard Gardner added that to enhance innovation, students should master at least one discipline early on [3]. Interdisciplinarity radiates from one or more central disciplines.

Innovation then involves an initial mastery of a field, the ability to remodel it, and the capacity to extend effectively these models beyond current boundaries. It is not an objective or random feature. It hinges on the interaction of a person's talents and preferences with internal or external knowledge. This suggests that for a constructed system, innovation depends on interactions between initial internal models, assigned tasks, the environment, and looping mechanisms that enable the system to remodel as well as develop new models.

3. MODEL AND REMODEL

To see how innovation might work in a constructed system, first we have to select an architecture for the system. Unavoidably, this is an arbitrary step. Based on what we already saw, we can start with a modeling system. This system has to be capable of remodeling as it interacts with itself and with an environment. It also should be modular and scalable to make it flexible enough to evolve in a dynamic environment.

Herman Hesse's novel *The Glass Bead Game* provides a model for a constructed system capable of innovation [4]. Hesse imagined a game that became a universal method for playing with all types of knowledge. Basically, the object of the game is to innovate. The protagonist, Joseph Knecht, is about to become the new Game Magister. This prompts his reflection about the state of the Game and concludes that it has problems that threaten its existence. The Game has become too abstract, too self-indulgent. It separated itself from the world and so it is reaching an impasse.

The Glass Bead Game has a hierarchical structure, with the elected Game Magister at the top. Then there is the community of players that is the source of innovation. This ensemble forms an evolutionary loop. The players innovate and the Game hierarchy selects innovations worth keeping, and in so doing affects the way the Game is played. Game Magister Knecht realizes that the problem does not lie at the level of the autonomous players, but in the hierarchical structure. It became closed and steered the game to levels of abstraction that disconnect it from the world that supports it. The way to save the game is to open that hierarchy again somehow. Only by reconnecting with the world can the Game continue to evolve in meaningful ways.

We can get other models of evolving systems from the work of John Holland for constructed systems [5], and from Gerald Edelman [6] and Rodolfo Llinás [7] for natural systems. They all share a layered architecture. Holland proposes a class of model he calls *constrained generating procedures* (cgp). They consist of elementary rules capable of generating behaviors. He points out that any constrained generating procedure can exhibit emergent properties. That is to say, any such system is capable of innovation. Holland proposes that elementary models can be networked to form more complex models and perhaps give rise to levels of emergence not accessible from the more basic components. He notes the close relation between emergence and innovation. Stuart Kauffman also suggested that creativity, innovation, and emergence have much in common in that they all point to the coming into existence of something new and significant [8].

Alex Meystel and James Albus present in *Intelligent Systems* [9] a more elaborate evolving system based on what they see as an elementary loop of functioning (ELF). The brain of the ELF architecture is a modeling component. It processes incoming information from sensors and generates appropriate behaviors. An initial model boots the system, but from there on it can be designed to learn on its own and evolve under the regulation of a value judgment system. Sensors and behavior generators link the ELF to the world. In a self-contained ELF, these connections lead instead to a simulator.

In an ELF with learning, the value judgment module is more than a static system of rules. It also can have an ELF architecture and evolve its rules through learning, and directly affect the models of the larger system. We can picture the learning module as an ensemble of neural nets capable of learning. And this learning is looped with the ELF's initial world models and value judgment rules that booted the system in the first place.

The question now is how to fine-tune this system so that it has the capacity to innovate effectively. This question brings up immediately issues of learning and evolution.

In his book *Intelligence Through Simulated Evolution*, Lawrence Fogel proposes that the basis of all evolutionary algorithms is an interplay of population-based random variations and selection of variations. But he wonders at the close of the book: "What theory of natural evolution (Lamarckian, Darwinian, and so forth) is most appropriate for addressing certain kinds of problems? Would it be advantageous to combine aspects of different theories?" [10]. For a constructed system, a purely random engine of evolution would take too long to yield outcomes that match the system's tasks. We consider nature aimless, so any sustainable outcome would do. But autonomous systems are built around tasks. Stephen J. Gould's sense of punctuated evolution [11] and even Lamarckian evolution, as Lawrence Fogel noted, may work more effectively with the task oriented modeling and remodeling of autonomous systems.

With constructed systems there is no need to get drawn into the interminable debates over natural evolution. Instead we can make choices in the construction, and then tinker until we get something reasonably adapted to our current needs and realities. This is, in essence, remodeling. It is an interactive process in the sense that it is pragmatic, playful, depends of multiple points of view, and it diversifies in the search for solutions [12].

So, instead of seeking to infuse randomness into the process of remodeling, I will use something still somewhat random but more subjective, so to speak, in the sense that it depends on the agents involved in the process. Rather than randomness, I would like to consider play and interaction.

4. PLAY, INTERACTION, AND EVOLUTION

Although the nature of play seems rather obvious, attempts to define it concisely have met with limited success. Play seems to escape unified definitions by its very nature [13] [14].

Perhaps the simplest image of play is jiggling. It appears random, yet depends on immediate factors. It is not abstract. A loose structure leaves room for play. Games provide structures to jiggle out different strategies and modes of playing. When it comes to child's play, Jean Piaget developed a comprehensive definition that hinges on play's adaptive function. Piaget considers adaptive behavior to be a combination of assimilation and accommodation to the world. In their most extreme forms, accommodation is imitation and assimilation is play. In imitation, our systems change to adjust somehow to what is perceived as external models. In play, the world is dismembered and absorbed selectively to fit the systems we already have, without changing them [15].

Play is not abstract in the sense that it is always tied to something with which someone plays. It could be a game, a musical composition, a toy, or just about anything. According to Piaget, the player uses a schemata or a model to play, as if it were a play tool or an excuse to play.

Piaget developed his view of play based on early childhood studies. But for adults, play may be more far reaching. Imitation in the form of modeling could also be playful. A model is a draft that imitates a phenomenon. If several models of the phenomenon are possible, then there is room to play when all models are considered at once. In other words, accommodation can also be playful when tried in many possible ways without settling down for just one view. So, in this extension of Piaget's conception of play, we see that it does have a wide range of modes beyond pure assimilation, ranging all the way to accommodation. What varies is the level at which playing is carried out.

Play is a loose fitting with room to jiggle. Flexible systems allow for play. Optimized systems do not. The process of play involves a player and an object of play. When playing changes the object there is interaction. In other words, interaction is a playful process that changes all participating components [16]. For there to be innovation, the internal remodeling of an autonomous agent could depend on an interactive type of play. The constructed system's internal task is to change its functioning models so as to affect its behavior in response to external changes in a dynamic environment. And these internal evolutions are innovations with respect to the system itself.

The question now is how to design and measure a system's interactive capacity. And again, for simplicity, we are considering only its internal capacity to evolve. We can safely assume that there is more than one way to go about doing this. Here I reflect on one model that seems viable based on the ELF architecture. The key feature is the process of remodeling within an ELF and how this process can be made to ripple effectively within a system.

For natural systems, Rodolfo Llinás thinks that creativity stems from errors of coordination. Suddenly a process will happen out of step with another, and out of that disjunction a new feature might emerge and acquire some permanence. Innovation is accidental and relentless. In this view, innovation in more random than deliberate.

For Edelman, innovation is far more deliberate. It originates in biological memory, which he describes as creative rather than only replicative. He argues that memory, just like perception, hinges on imagination and results from mechanisms of reentry consisting of feedback and feedforward loops.

Meystel and Albus combine both views. They develop a loop process for constructed systems. Feedforward is directly linked to planning, which in turn involves learning from experience in the domain of imagination. They formulate a principle of creativity as a combinatorial technique of decision-making. This happens across many linked levels or scales. They call this crucial detail *multiresolution*. It produces a complexification through connections among simpler structures nested over different scales.

Multiresolution loops us back to the Glass Bead Game model for a moment. One key feature of the Game is that it happens at a multitude of linked levels. It is not like chess, where there is only one game level. In the Glass Bead Game, an innovative move on its board has consequences that ripple through entire fields of knowledge, from history to the arts and sciences. A new move inspires remodelings on all levels at all resolutions. The Glass Bead Game is profoundly interactive. The selection process is also critical. A hierarchy of players, all the way up to the Game Master, the Magister Ludi, assigns value to innovations and favors some over others. This valuation system if always in flux, as the novel well shows, so that there are

loops formed that alter valuation weights and cause predictable as well as unpredictable revaluations. Finally, histories of the Glass Bead Game from different points of view help preserve innovations for future games.

5. ENGINE OF INNOVATION

In *Intelligence Reframed*, Gardner lists seven factors that can enhance creativity in people. The first six ones hold no surprises: they stress the importance of taking chances, excel in at least one pursuit, self-discipline, a challenging environment, supportive peers, and a supportive family configuration. But the seventh factor has a striking edge. Gardner proposes that creativity is enhanced by a physical, psychic, or social obstacle or anomaly that makes a person marginal within his or her group. The reason for this factor is that normality within one's community—averageness, as Gardner puts it—does not spur creativity. We are familiar with the image of the creator as a person who is strange in some way: absent-minded, geek, rebel, a different drummer, someone who verges on being obsessive-compulsive, and so on.

Yet creative people are able to function in their communities rather than end up in mental institutions for more than a brief visit. This means that creative people have the capacity to repair and compensate continuously. We all have that capacity, but the focus on creativity brings the value of this mechanism to the forefront. I link this factor immediately with the value of imperfection that we saw at the beginning. Imperfection fuels innovation through compensatory and repair mechanisms that are sort of the immune system of the imagination. Innovation could then be pictured as stemming from an immune mechanism coupled with a selection process and a well-tuned construction system.

We now touched upon all the components that can be used to model a constructed system that may be capable of innovation within assigned tasks. The interactive system would have the following architecture divided into six features:

• Building blocks of elementary functioning loops that have memory and remodeling capacities. Neural nets can produce these capacities.

• A layered network of such blocks so that there are external and internal inputs at all levels of the system.

• Network loops can synchronize the entire system and subsystems so that components of the system can interact in various ways, especially in the formation of higher-level memories, remembrances, and remodelings.

• Some of these loops are organized as repair or immune mechanisms triggered by perceived imperfections or imbalances.

• System outputs at all levels can synchronize and yield new internal or external outputs.

• The system contains fuzzy components or links. These can be seen as imperfections capable of initiating play.

Finally, we can speculate on how to gauge qualitatively the capacity to innovate. In a constructed system we have sufficient closure to gauge what might constitute innovation with respect to a prior state of the system. This greatly simplifies the task because now we don't have to look at instances of innovation with respect to the world but with respect to a system that for practical purposes can be considered closed. In other words, to examine the autonomy of a system, we could gauge its capacity to innovate from the point of view of ontogeny rather than phylogeny.

In a dynamic environment, an autonomous system needs to be able to innovate, at least internally, in order to solve problems that fall within its task. A measure of this capacity can supplement any other developed measures of performance of autonomous systems. We can then gauge the following features:

• The capacity of subsystems for self-repair or compensation.

• The overall capacity of the system for self-repair or compensation.

This could be carried out using simulations of damages that the system can be expected to sustain both internally and externally, and might be able to repair without preprogramming.

We can also gauge the following active features:

• Expose the system to varying levels of repetitions of a sequence of new feature that it might encounter in a dynamic environment without preprogramming, and see how it learns from the experience.

• Change internal models in subsystems and see how the system remodels to deal with the change.

6. CONCLUSION

In this presentation I proposed that innovation is a response to change. To function autonomously in a dynamic environment, a constructed system has to be capable of innovating to some degree. This capacity can be modeled as a repair and compensation mechanism. It can be measured with respect to specific tasks assigned to the system by having it react to selected imperfections and gauging the results.

This view makes innovation seem reactive. But it can become increasingly proactive based on the tasks assigned to an autonomous system. Human innovation does look

forward. It embraces change because we are driven by curiosity to explore and play with all accessible possibilities no matter what the discipline. Perhaps by enhancing the capacity of constructed systems to play we may render them more curious and innovative.

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